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## (54) Method and apparatus for electronic data compression

(57) A method and apparatus for efficiently transmitting digital image data is disclosed. More specifically, the present invention accomplishes fast data transmission by analyzing (504-508) the content of input data, and then retrieving (660) data that closely matches that which would be produced if the data were subjected to some form of data compression from storage. The retrieved data is transmitted (680) to the retrieving device, thereby eliminating the need for very time consuming data compression processes.

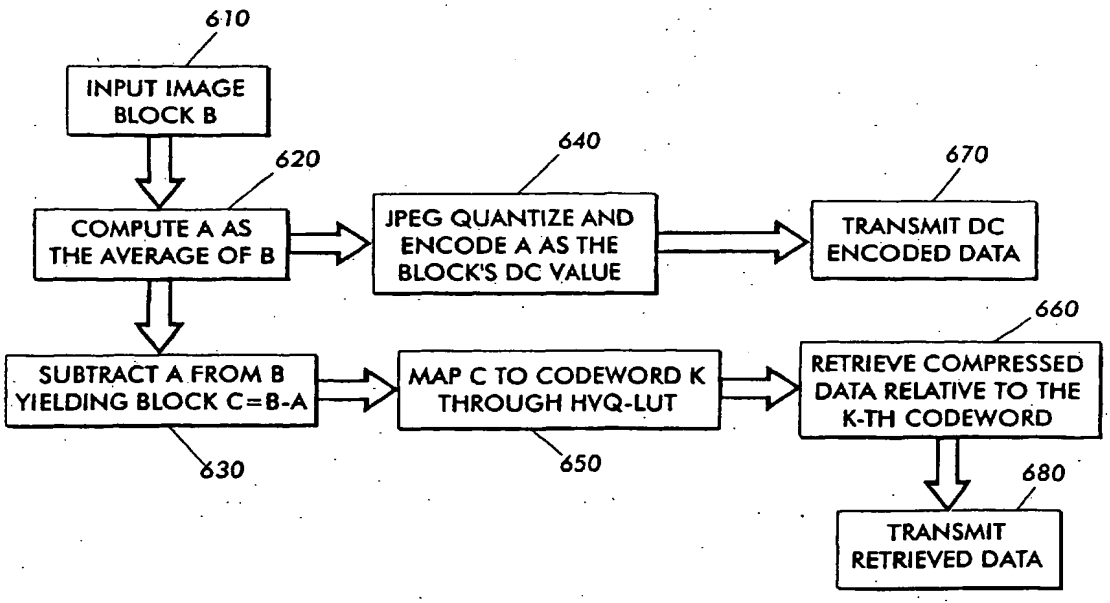


FIG. 7

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## Description

**[0001]** The present invention is directed to a method and apparatus for transmitting data without performing conventional data compression. More specifically, the invention accomplishes image compression by analyzing the content of an image and transmitting data that is closely matched to that which would be produced if conventional data compression was allowed to take place.

**[0002]** The transmission of electronic data via facsimile machines and similar devices has become quite common. Efforts to transmit significantly larger volumes of this data within a substantially shortened period of time are constantly being made. This is true not only to allow data to be sent from one location to another at faster speeds and to cause less inconvenience to the user, but to enable more complex data to be transmitted between the same locations without drastically increasing the required transmission time. For example the facsimile transmission time for a detailed halftoned image will be many times more than that of a simple sheet of black text on a white page when using the same fax machine. By the same token, fax transmission of a color image will require an even greater amount of time than its greatly detailed halftoned counterpart. It is desirable to be able to transmit documents that contain these types of data - as well as others - within a short period of time.

**[0003]** In accordance with one aspect of the invention there is provided a method of improving the speed and efficiency of electronic data compression, which includes: obtaining an input image data block which includes discrete values that represent light intensity in an image; analyzing a content of the input image data block and mapping the image data block to a single codeword using at least one look up table; retrieving stored output image data that will closely match that which would be produced by compressing the input image data; and transmitting the retrieved output data to a receiving device.

**[0004]** In accordance with another aspect of the invention there is provided a method of improving the speed and efficiency of electronic data compression, which includes: obtaining an input image data block which includes discrete values that represent light intensity in an image; computing an average signal value for the data block; forming a different block with signal values that equal a difference between signal values of the input data block and the computed average signal value; analyzing a content of the difference block and mapping the difference block to a single codeword using at least one look up table; retrieving stored output image data that will closely match that which would be produced by compressing the difference data block; encoding the computed average signal value; and transmitting the encoded computed average signal value and the retrieved output data to a receiving device.

**[0005]** In accordance with another aspect of the invention there is provided an apparatus for transmitting a reproduction of an original image from a sending location to a receiving location, including: a scanner which acquires the original image and which digitizes light that is reflected from the original image to form input digital image data that includes pixel values which represent the light intensity throughout the original image; a central processing unit which includes a segmenter which separates the input data into a plurality of input data blocks; an image analyzer which analyzes the content of an input data block, and maps the input data block to a single codeword; a memory with output data blocks stored therein; a retriever which selects an output data block based upon the input image data block content, and transfers the output data block from a memory to the central processing unit; and a transmitter which sends the retrieved output data to a receiving device.

**[0006]** Other features and advantages of the present invention will become apparent as the following description proceeds and upon reference to the drawings, in which:

Figure 1 is a generalized block diagram illustrating general aspects of a facsimile machine that may be used to practice the present invention;

Figure 2 contains a diagram that illustrates how digital image data is grouped into blocks according to the present invention;

Figure 3 is a generalized diagram depicting one embodiment of the present invention;

Figure 4 is a schematic illustration of HVQ which is used in one embodiment of the present invention;

Figure 5 contains a detailed illustration that shows one embodiment of how input blocks may be mapped to codewords according to the present invention;

Figure 6 is a flow chart illustrating generally, the steps performed to analyze input image data according to the present invention; and,

Figure 7 is an illustration of the preferred embodiment of the invention which includes an implementation that simulates JPEG compression.

The present invention is directed to a method and apparatus for compressing complex digital image data to enhance the efficiency of data transmission.

**[0007]** Referring now to the drawings where the showings are for the purpose of describing an embodiment of the invention and not for limiting same, Figure 1 is a block diagram showing structure of an embodiment of a facsimile (fax) apparatus 10 according to the present invention. Fax 10 includes a CPU 12 for executing controlling processes and facsimile transmission control procedures, a RAM 14 for controlling programs and a display console 16 with various buttons and/or switches for controlling the facsimile apparatus and LCDs or LEDs for reviewing the status of system operation. A scanner 20 is also included for acquiring an original image and generating image data therefrom. Image

processing unit 22 is included to perform encoding and decoding (compression and decompression) processes between n image signal and transmitted codes. Significantly for purposes of this invention, fax 10 includes or interfaces with a modem 24, which is a modulating and demodulating device that transmits and receives picture information over telephone lines to a compatible receiving device 26, such as another facsimile machine, a printer, computer terminal or similar apparatus.

**[0008]** As stated above, image processing unit 22 is used to compress and decompress image signals and transmitted codes. One common method of compressing and decompressing image signals is through use of the JPEG (Joint Photographic Experts Group) standard. However, many forms of compression are available and the invention is not limited to this embodiment. As indicated above, an original document is acquired by a scanner 20, which digitizes light that is reflected from the image to form digital image data. Digital image data comes in the form of picture elements or "pixels" which indicate the intensity of the light that is measured at discrete intervals throughout the surface of the page.

**[0009]** With reference to Figure 2 pixels 120 emit light signals with values that indicate the color or, in the case of gray scale documents, how light or dark the image is at that location. As those skilled in the art will appreciate, most pixels 120 have values that are taken from a set of discrete, non-negative integers. For example, in a color document, individual separations are often represented as digital values in the range 0 to 255, where 0 represents no colorant (i.e. when CMYK separations are used), or the lowest value in the range when luminance-chrominance separations are used. Consequently 255 represents the maximum amount of colorant (for CMYK) or the highest value in the range (i.e. maximum light/white, red and yellow respectively for L*a*b*). In a gray-scale pixel map this typically translates to pixel values which range from 0, for block, to 255, for the whitest tone possible.

**[0010]** In one embodiment of the invention, pixels 120 which represent the entire set of digital image data are separated into blocks 102. In the preferred embodiment block 102 will be configured with eight pixels extending in the horizontal direction and eight pixels extending in the vertical direction, and the invention may be used with JPEG compression. However, other block configurations are possible and compatibility with JPEG compression is not an absolute necessity. Those skilled in the art will recognize that a smaller or larger block size might be chosen when it is desired to preserve more or less image detail. In fact it should be noted that while the horizontal and vertical dimensions are identical in the embodiment of input block 102 described here, this is not a requirement for practicing the present invention. For example, a non-square block might be chosen if the image was generated for a device possessing asymmetric resolutions in the vertical and horizontal directions.

**[0011]** As stated earlier, compressing large volumes of data can be a very time consuming task. The present invention substantially reduces the amount of time required to process and transmit a digital image without actually compressing the data, while retaining image quality.

**[0012]** In Vector Quantization (VQ), an image processing operation well known in the art, K symbols that have N bits each are assigned to a single B bit codeword, where $B < NK$. For example sixteen eight-bit input strings might be assigned to a twelve-bit codeword. Thus, in this example, there will be enough codewords to represent only the 4096 ($2^{12}$) most representative blocks of the sixteen input symbols. Considering that goal is to represent entire images, it is easy to see that the number of bits used to represent an entire image using codewords is substantially less than the number that would be required to represent the image using the original blocks. Codewords that are produced by vector coding can be stored or transmitted to another location or device, and later decoded - mapped back - to K symbols.

**[0013]** Turning now to Figure 3, in the present invention output image data blocks 202 are stored in memory 206 in each facsimile or other transmitting device 10. The invention includes an image analyzer 204, which analyzes the content of the input block 102 and then retrieves from storage, an output block 202 that will closely simulate the data that would have been produced by the selected compression method had it been allowed to take place. In the preferred embodiment of the invention, JPEG will be the selected compression method. But again, the invention is not limited to JPEG compression and numerous other forms compression may be implemented as well. Specifically, this embodiment uses Hierarchical Vector Quantization (HQV) to analyze the activity of each input block 102 in the scanned image. Once the input block 102 is analyzed, the proper output block 202 is selected, retrieved from memory 206, and transmitted to receiving device 26 for output. Codewords, codebooks and the entire mapping process are prepared in advance of operation the present invention. Thus, the only calculations that are required during operation are to compare input data blocks 102 to the codebook and select the appropriate codeword.

**[0014]** Referring now to Figure 4, a general description of HVQ will now be provided. As indicated earlier, multiple N-bit symbols are mapped to a single B-bit codeword using a series of Look Up Tables (LUTs). As shown in the illustration, two N-bit symbols are mapped to an output codeword 306 at the first level using LUT 304, which has $2^{2N}$ entries. As shown, the total number of inputs is reduced by a factor of two at the each level. The process is repeated until only one output remains, preferably by grouping codewords in a direction perpendicular to that used for the previous level (best indicated in FIG. 5). Repeating the process results in the mapping of larger and larger blocks of data to a single codeword.

**[0015]** HVQ allows for a rough approximation of the content of each input image block using simple look-up table operations. The final codeword represents a block approximation and can, therefore be directly mapped to other quantities which describe certain characteristics of the approximated block, such as block activity. HVQ codebook design methods follow standard VQ codebook design algorithms and are usually performed by designing the codebooks for a single level at a time. Some drawbacks of using VQ in a non-hierarchical manner are that codebook design is often very complex, and that large amounts of time are usually required to search through the codebook and to match inputs to the appropriate codeword. While the present invention allows codebook design to be performed off-line, block matching searches must be performed on-line. Although block matching is somewhat time consuming, transmission of large volumes of data is much faster using the present invention than it would be using standard compression techniques.

**[0016]** HVQ is incorporated into image analyzer 204 to select the codeword that is linked to the data stored in memory 206 which most closely matches that which would result from compressing input block 102. The relationship between input blocks 102 and N-bit inputs is illustrated with reference to FIG. 5, using an 8 x 8 input block. As shown, pixels 120 in the block are initially grouped in pairs, and each pair is represented by a codeword 306 that references data that appears most similar to that of the input data according to a predetermined distance measure. Visual closeness when viewed with the human eye or some form of statistical analysis of the data contained in the block are two reasonable measurement criteria, but others are possible and the invention is not limited to these embodiments.

**[0017]** Pairs of codewords 306 are then grouped, preferably in the direction perpendicular to that used for the initial grouping, to produce next level codeword 310. Again, codeword 308 represents image data that will most closely match that contained in input codeword pair 310. Grouping and mapping continues until a single codeword 314 remains. Codeword 310 will represent the data that most closely matches the entire input block 102. (It should be noted here that the numbering final codewords in Figures 4 and 5 does not match because fewer levels are shown in Figure 4 than in Figure 5. The final output word would be represented by the same reference number if the same number of levels are shown in both drawings.)

**[0018]** Figure 6 contains a flow chart showing the operating details of image analyzer 204. Beginning with step 502 input block 102 is input to image analyzer 204 which, in the preferred embodiment of the invention, is a system based on HVQ. Each pair of N-bit inputs 302 is mapped to a single codeword 306 using a look up table 304 as indicated in step 504.

**[0019]** Grouping the N-bit inputs 302 into pairs and outputting a single codeword 306 therefrom is the preferred embodiment, but use of this configuration is not required to practice the invention. For example, if the shape of the input block or the chosen number of bits, suggests that grouping three or more N-bit inputs 302 would be desirable, the invention could be adapted to accommodate this requirement. Further, if outputting multiple codewords 306 when more than two inputs 302 have been grouped is somehow advantageous, the invention could be adapted to perform this task as well. What is necessary to fully benefit from the present invention is for the number of inputs 302 to exceed the number of codewords 306. Thus, while mapping five N-bit inputs 302 to three N-bit codewords 306 would be desirable, mapping three N-bit inputs 302 to five N-bit codewords 306 would not typically be the best approach.

**[0020]** Assuming that more than one codeword 306 has been generated by the initial level division of input block 102, the codewords produced in the first level must be grouped in pairs and a second LUT 308 must be used to map each pair of resulting codewords 306 to a second level codeword 310. This second mapping reduces the number of codewords 310 by a factor of two over the number of codewords 306 from the previous level. The mapping pairs of codewords to a single codeword in the next level continues in hierarchical fashion until all N-bit inputs that make up input block 102 can be mapped to a single codeword at the last level. That is, LUT levels must continue to be applied hierarchically to each pair of output codewords from the previous level until a single output codeword 314 is generated.

**[0021]** Still referring to Figure 6, this continued mapping is shown by the loop between steps 504, 506 and 508. It should be noted that a different LUT is used for mapping at each HVQ level, and that the LUTs at all levels above the first have been designed such that the inputs are codewords, rather than image data. The output from these higher level LUTs are codewords which represent the input codewords. Once the number of output codewords has been reduced to one, that final codeword 302 is used to select an output block 302 that consists of data that will closely match that which would have been produced by data compression. Output block 202 will be transmitted in a bit stream over communication lines, most commonly telephone lines, to the appropriate compatible device at the receiving location, and outputting the digital image data at an output device 26 (i.e. fax, computer terminal, video display, printer).

**[0022]** In the preferred embodiment of the invention HVQ is incorporated to simulate JPEG compression. Specifically, the data associated with the codeword that is retrieved and transmitted is a representation of the ACC (AC coefficient) of a block. Turning to Figure 7, receiving unit 710 retrieves an input block 102 from the input image ad computes its average "A" at 620. The pixels in input data block are subtracted by A at 630 to obtain a new zero-mean block "C" wherein C = B-A. The average of zero-mean block C is used as the DCC (DC

coefficient) for the compression of the block, which is then submitted at 640 to quantization, DPCM, and encoding according to the teachings of the JPEG standard, well known in the art. The encoded compressed data (relative to the DCC) is then transmitted in 670 to a receiving device. In this embodiment of the invention, A represents the DCC of input data block 102, while block C corresponds to its ACC.

**[0023]** Block C is submitted to an analysis through LUT-mapping 650 as previously described being mapped to a codeword index K. In the preferred embodiment, the mapping is performed according to the HVQ method of pairing codewords hierarchically in a block, but the invention is not restricted to this form. The retrieved index is used to address the precomputed JPEG compressed data relative to the ACC of the approximating block. This data is retrieved in 660 and output in 680 to complete the process of compressing the ACCs and the DCC of a block. While the DCC is compressed in a regular manner, the data relative to the ACCs is estimated from the input data through a fast analysis process, without resorting to perform the conventional steps for JPEG compression.

## Claims

1. A method of electronic data compression, comprising:

   a) obtaining (502) an input image data block which includes discrete values that represent light intensity in an image;
   b) analyzing (504-508) a content of said input image data block and mapping said image data block to a single codeword using at least one look up table;
   c) retrieving (660) stored output image data that will closely match that which would be produced by compressing said input image data; and
   d) transmitting (680) said retrieved output data to a receiving device.

2. A method as claimed in claim 1, wherein said analyzing step is performed using hierarchical vector quantization.

3. A method as claimed in claim 1 or claim 2, wherein for said retrieving step, said stored data simulates an AC coefficient that would be produced by performing JPEG compression on said input image data block.

4. A method as claimed in claim 3, wherein said stored data has been provided by a method comprising the steps of:

   a) computing an average of all signal values in said input block;
   b) subtracting said signal average value from said input block signal values to obtain a zero-mean block having zero-mean signal values;
   c) calculating an average of said zero-mean signal values, and submitting said zero-mean signal average to a quantization step, a DPCM step, and an encoding step according to the teachings of the JPEG standard; and
   d) transmitting said encoded compressed data to a receiving device.

5. A method as claimed in claim 4, further comprising:

   a) mapping said zero-mean block to a codeword using a look up table;
   b) using said codeword to address said stored data; and
   c) retrieving said stored data and outputting said retrieved data to a receiving device.

6. A method according to any of the preceding claims, wherein step b) comprises:

   i) computing an average signal value for said data block;
   ii) forming a difference block with signal values that equal a difference between signal values of said input data block and said computed average signal value; and
   iii) analyzing a content of said difference block and mapping said difference block to a single codeword using at least one look up table; and wherein step d) comprises:
   i) encoding said computed average signal value; and
   ii) transmitting said encoded computed average signal value and said retrieved output data to a receiving device.

7. An apparatus for improving the speed and efficiency of electronic data compression, comprising:

   a) means (20) for obtaining an input image data block which includes discrete values that represent light intensity in an image;
   b) means for analyzing (22) a content of said input image data block and mapping said image data block to a single codeword using at lest one look up table;
   c) means for retrieving (12) stored output image data that will closely match that which would be produced by compressing said input image data; and
   d) means for transmitting (24) said retrieved output data over telephone lines to a receiving device.

8. Apparatus according to claim 7, wherein the obtaining means comprises a scanner (20) which acquires the original image and which digitizes light that is reflected from said original image to form input digital image data that includes pixel values which represent the light intensity throughout the original image; and the analyzing means comprises a central processing unit (12) which includes a segmenter which separates said input data into a plurality of input data blocks, an image analyzer (22) which analyzes the content of an input data block, and maps said input data block to a single codeword, and a memory with output data blocks stored therein.

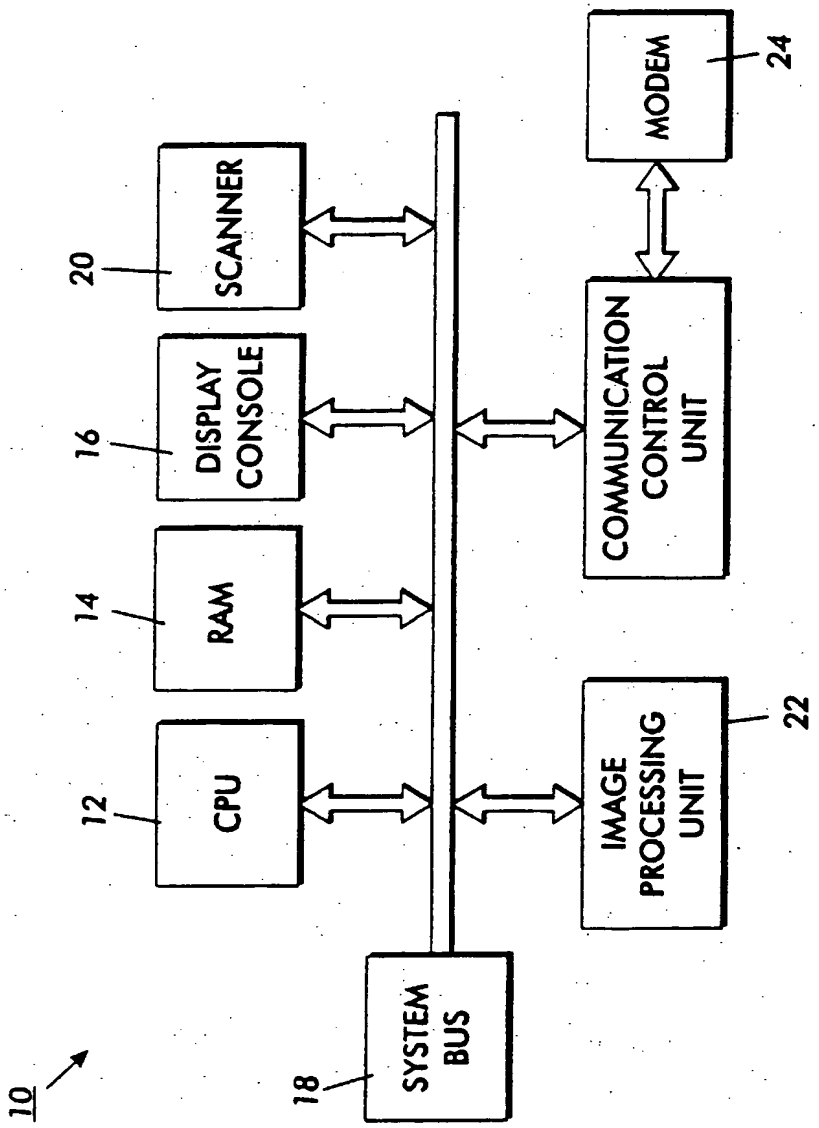
10
18
SYSTEM BUS
12
CPU
14
RAM
16
DISPLAY CONSOLE
20
SCANNER
22
IMAGE PROCESSING UNIT
COMMUNICATION CONTROL UNIT
24
MODEM

FIG. 1

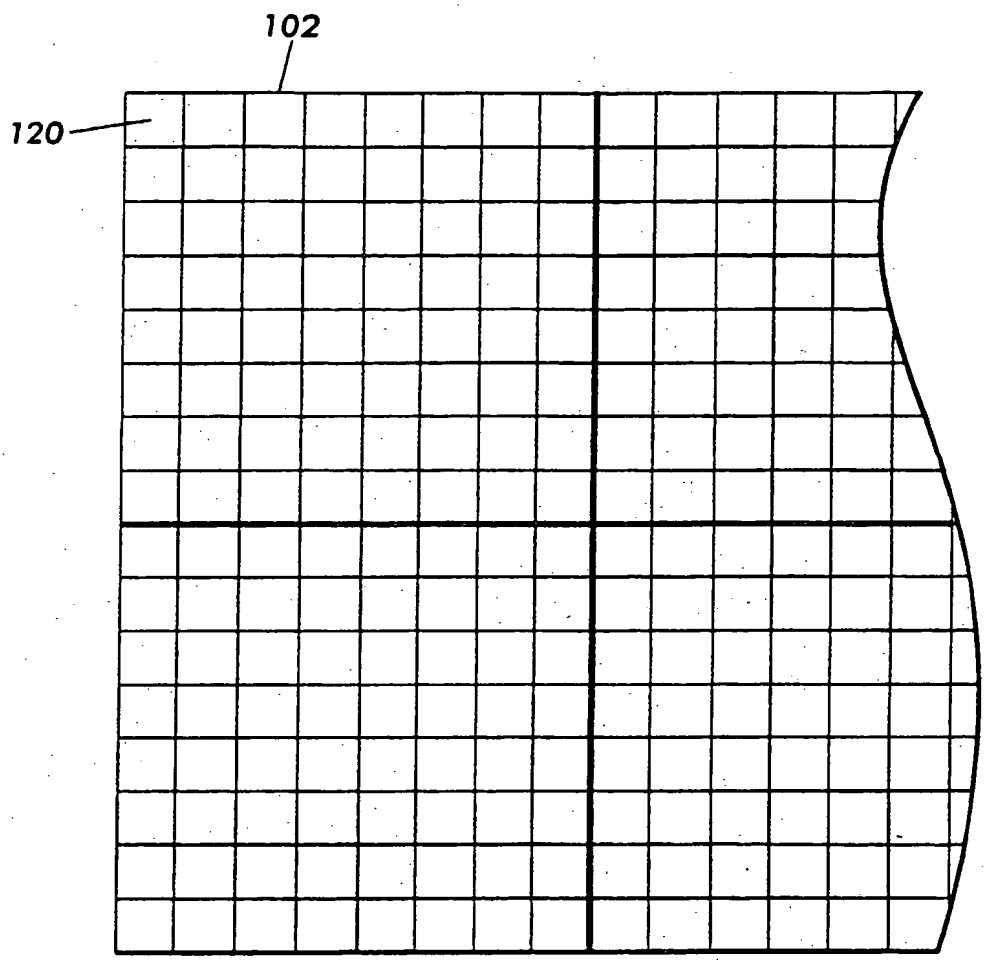


FIG. 2

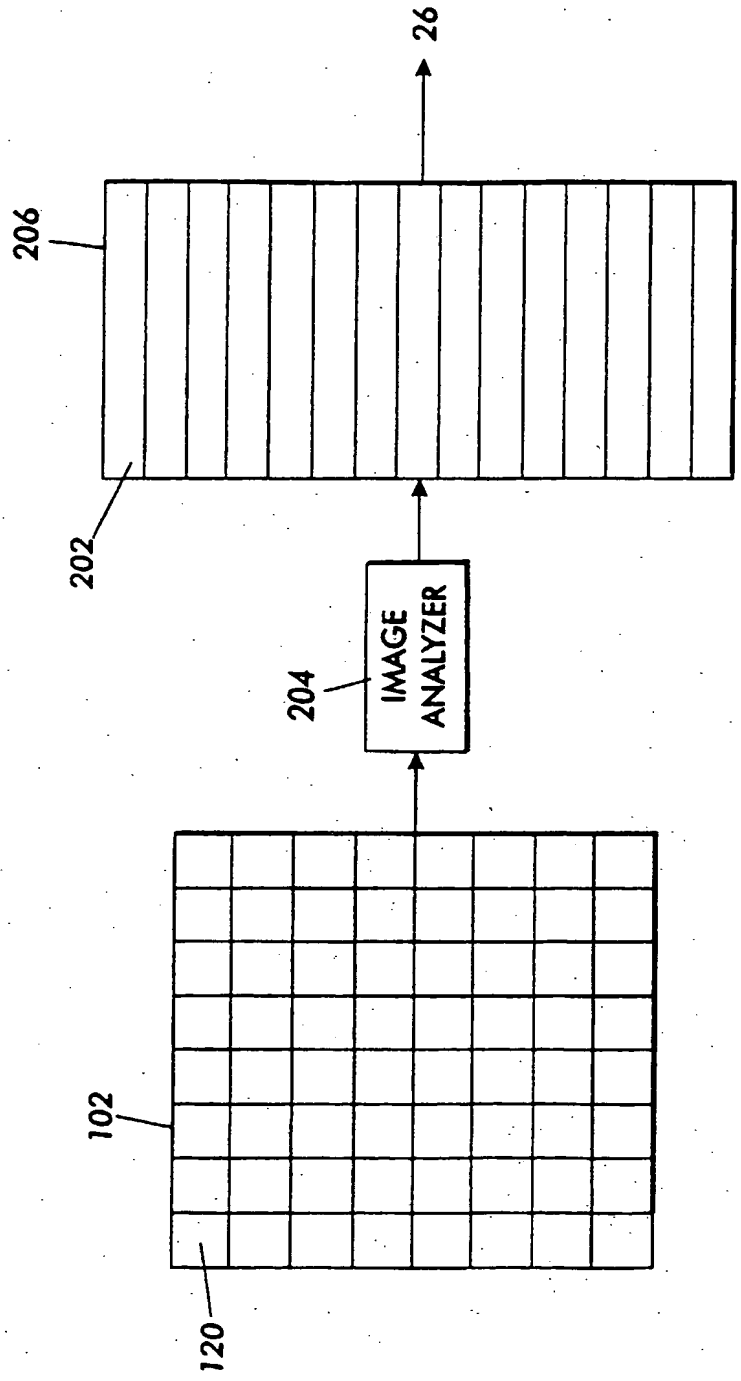


FIG. 3

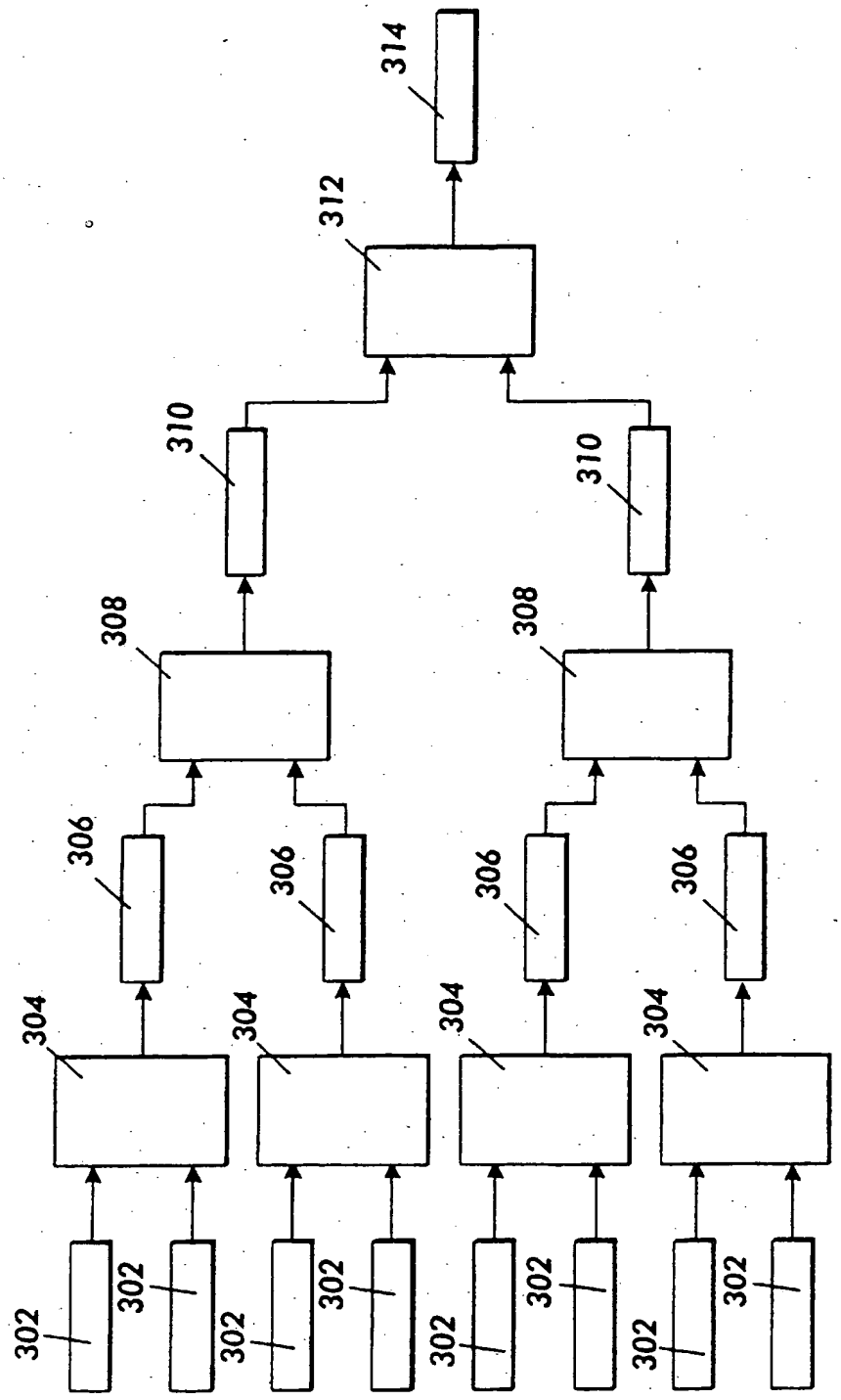
314
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FIG. 4

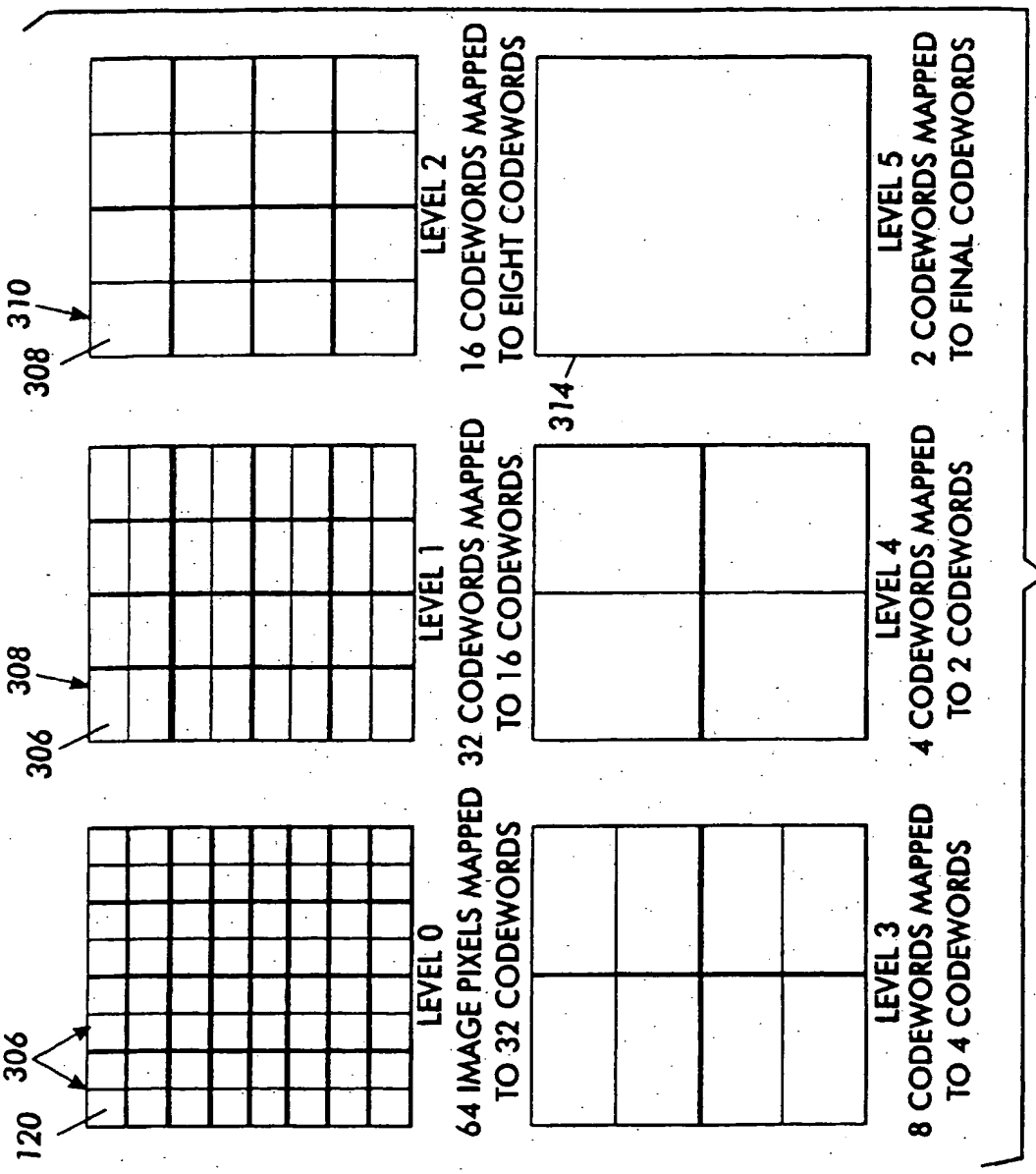
120
306
64 IMAGE PIXELS MAPPED TO 32 CODEWORDS
LEVEL 0
306
308
32 CODEWORDS MAPPED TO 16 CODEWORDS
LEVEL 1
308
310
16 CODEWORDS MAPPED TO EIGHT CODEWORDS
LEVEL 2
314
8 CODEWORDS MAPPED TO 4 CODEWORDS
LEVEL 3
4 CODEWORDS MAPPED TO 2 CODEWORDS
LEVEL 4
2 CODEWORDS MAPPED TO FINAL CODEWORDS
LEVEL 5

FIG. 5

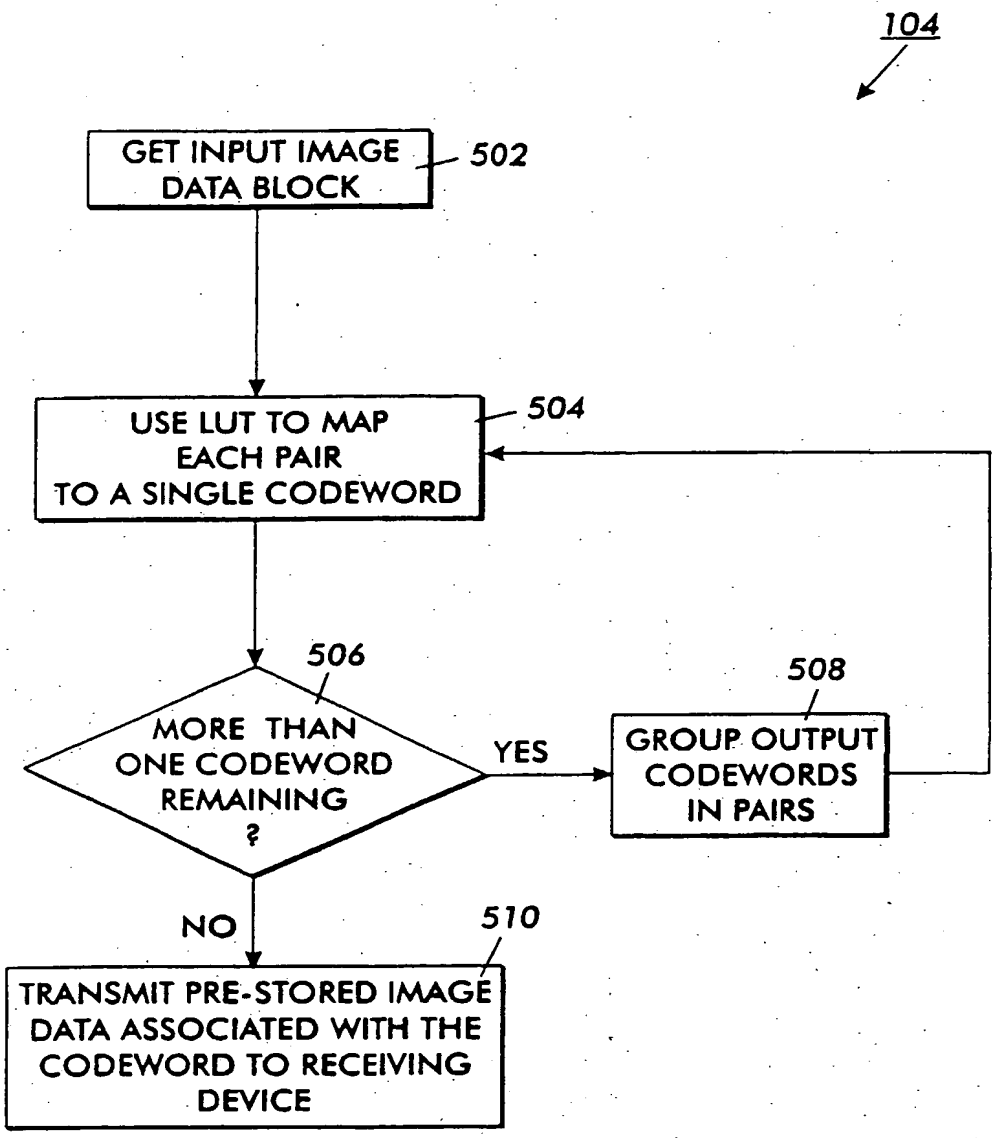
104
GET INPUT IMAGE DATA BLOCK
502
USE LUT TO MAP EACH PAIR TO A SINGLE CODEWORD
504
506
MORE THAN ONE CODEWORD REMAINING ?
YES
508
GROUP OUTPUT CODEWORDS IN PAIRS
NO
510
TRANSMIT PRE-STORED IMAGE DATA ASSOCIATED WITH THE CODEWORD TO RECEIVING DEVICE

FIG.6

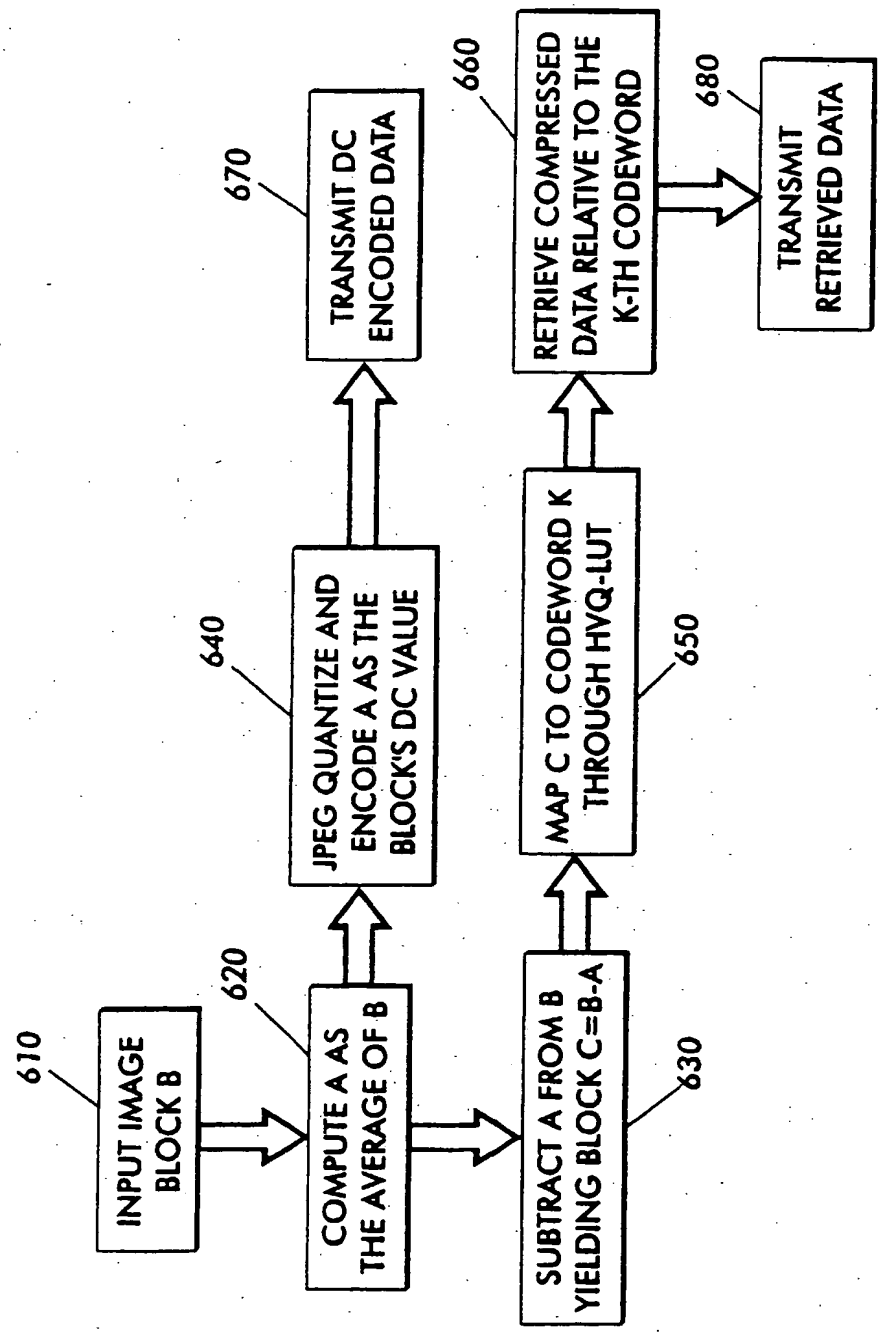
610
INPUT IMAGE BLOCK B
620
COMPUTE A AS THE AVERAGE OF B
630
SUBTRACT A FROM B YIELDING BLOCK C=B-A
640
JPEG QUANTIZE AND ENCODE A AS THE BLOCK'S DC VALUE
650
MAP C TO CODEWORD K THROUGH HVQ-LUT
660
RETRIEVE COMPRESSED DATA RELATIVE TO THE K-TH CODEWORD
670
TRANSMIT DC ENCODED DATA
680
TRANSMIT RETRIEVED DATA

FIG. 7

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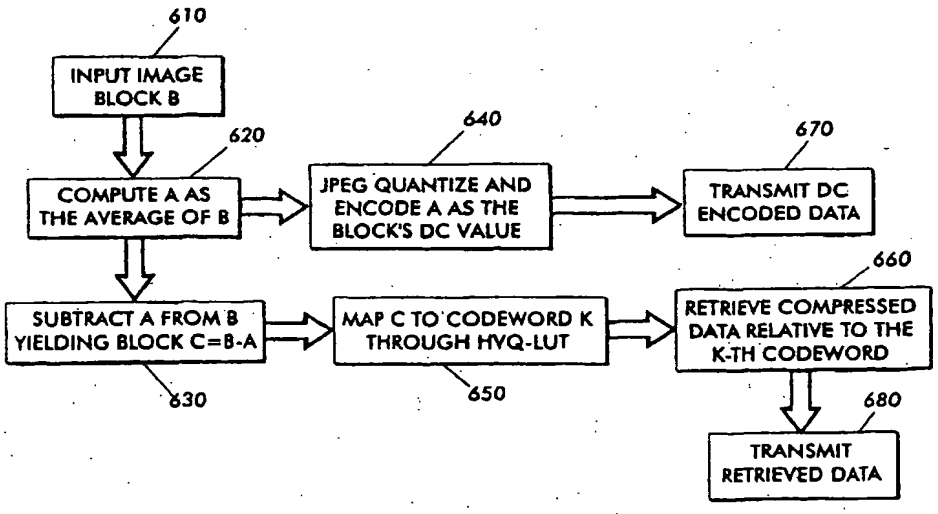


FIG. 7

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European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 99 30 9701

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
|---|---|---|---|
| X | WO 97 36376 A (CHADDHA NAVIN ;VXTREME INC (US)) 2 October 1997 (1997-10-02)<br>* page 20, line 28 - page 21, line 3 *<br>* page 21, line 18 - page 23, line 14 *<br>* page 34, line 1 - line 18 * | 1-3,6-8 | H04N7/26<br>H04N7/28 |
| Y | | 4,5 | |
| X | HUANG S-C ET AL: "A CONSTRAINED VECTOR QUANTIZATION SCHEME FOR REAL-TIME CODEBOOK RETRANSMISSION"<br>IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE INC. NEW YORK, US,<br>vol. 4, no. 1,<br>1 February 1994 (1994-02-01), pages 1-7, XP000439479<br>ISSN: 1051-8215<br>* page 1, paragraph I *<br>* page 2, paragraph II.4 *<br>* figure 1 * | 1,2,6-8 | |
| Y | | 4,5 | |
| A | | 3 | |
| X | RAMAMURTHI B ET AL: "CLASSIFIED VECTOR QUANTIZATION OF IMAGES"<br>IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE INC. NEW YORK, US,<br>vol. COM-34, no. 11,<br>1 November 1986 (1986-11-01), pages 1105-1115, XP000676210<br>ISSN: 0090-6778<br>* page 1107, paragraph III *<br>* page 1109, paragraph V * | 1,2,6-8 | |
| A | * figures 3-5 * | 3-5 | |

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H04N
G06T
H03M

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 26 October 2001 | Lombardi, G |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 9701

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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